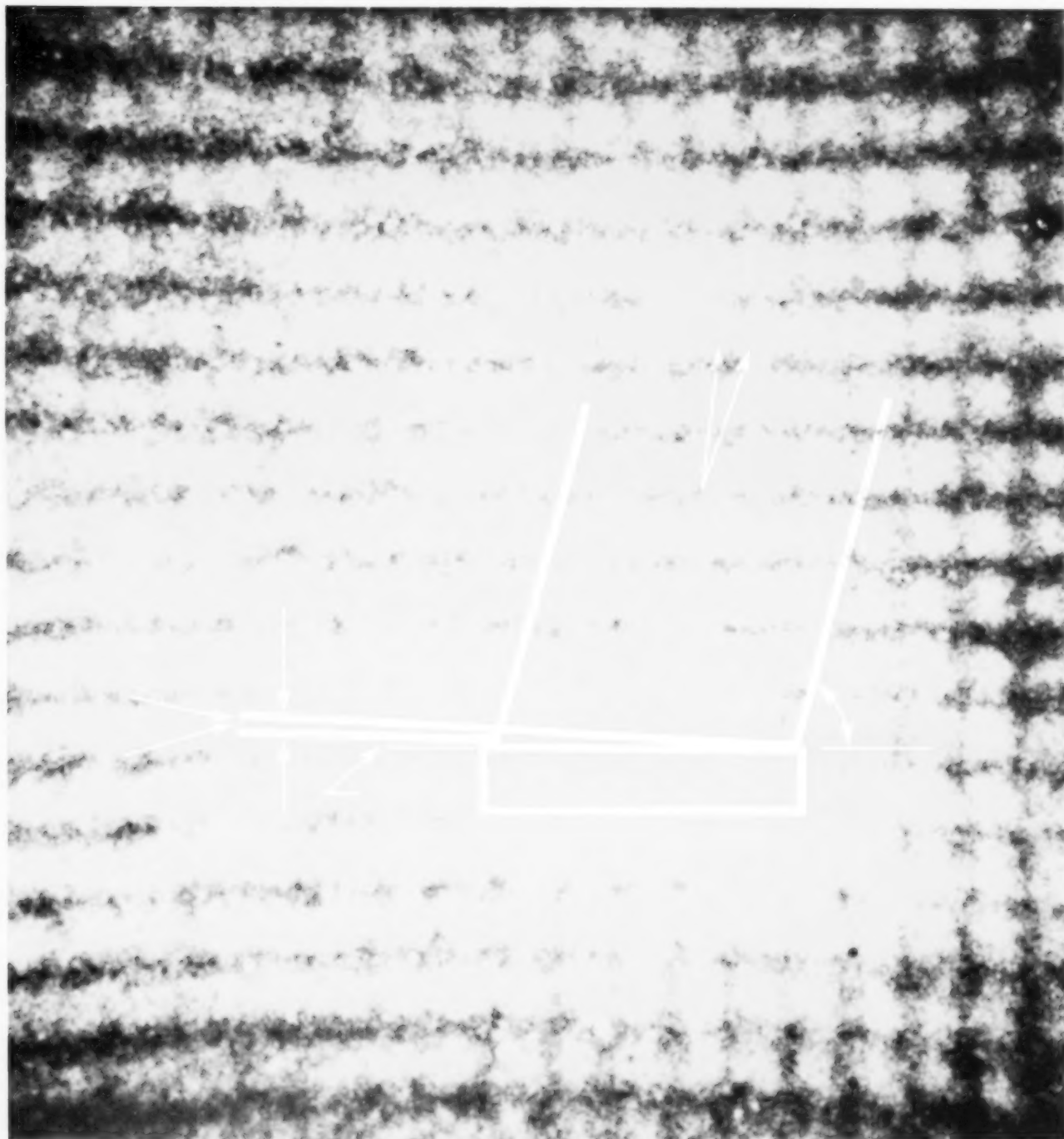


DIMENSIONS

The magazine of the
National Bureau
of Standards
U.S. Department
of Commerce

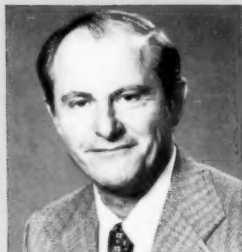
March 1979



MAGNIFYING AN X-RAY IMAGE. See page 18.

COMMENT

THE NEED FOR BETTER NONDESTRUCTIVE EVALUATION TECHNOLOGY



Time, money, and sometimes even lives could be saved if we had reliable and economic ways to find defective components so that they could be replaced be-

fore they failed in service. New and improved methods for nondestructive evaluation offer this promise.

Nondestructive evaluation, or NDE, is the term for a multidisciplinary group of testing and measurement methods that can be used to examine and evaluate materials and structures without damaging them. The methods vary from straightforward visual inspection to sophisticated approaches in which three-dimensional images of objects are reconstructed from x-ray, neutron, or ultrasonic measurements.

It sounds easy, but in fact it is much easier in theory than in practice. We often find that NDE measurements are neither as reproducible nor as thorough as we would like. When a given object is evaluated by different inspectors, different equipment, or different methods, the results do not always agree. Furthermore, the results do not always reveal sufficient information about a defect—its type, size, orientation, and location—to permit a meaningful evaluation of the object's performance capabilities.

The National Bureau of Standards' Office of Nondestructive Evaluation, in the National Measurement Laboratory, addresses these problems in two ways: We direct a vigorous research and development effort throughout the Bureau, and we try to focus outside attention on current needs in NDE. Our NDE Program encompasses technical work on more than 10 different NDE methods, carried out by scientists and engineers in more than 20 NBS divisions. The strong standards orientation of the program is reflected in the following examples: A calibration service for aluminum ultrasonic reference blocks

(used to adjust ultrasonic systems) is operational; calibration services for electrical conductivity measurements (used to sort, identify, and characterize alloys) are almost ready; the development of a well characterized crack plate (to verify the performance of liquid-penetrant systems) is nearing its final stages. Within the next few years, additional standards and services will be available. These will permit the traceability to NBS of several NDE measurements and offer the prospect of improving significantly the reproducibility of NDE measurements in industry.

The development of standards for NDE measurements represents the Bureau's response to the most urgent, near-term needs in the industrial NDE community. Other aspects of the NDE Program are directed toward longer-term needs, such as new and improved methods for detecting defects that could lead to premature failures. Examples include theoretical studies of the flaw detection capabilities of eddy currents; research on the relationship of theory to improved eddy current inspection systems; and development of advanced acoustic-emission testing concepts for the continuous monitoring of structures.

Defects such as cracks, seams, pores, and inclusions are not the only causes of premature failure in materials. Undesirable variations in material properties such as hardness or grain size, or improper processing that creates detrimental residual stresses, can also degrade performance. Therefore, part of the NBS effort is directed toward better nondestructive measurements of material parameters. One example is the development of a tomographic system which will enable three-dimensional images to be reconstructed from measurements of a number of ultrasonic variables such as scattering, absorption, and acoustic velocity. Such images will provide tools for characterizing material variations.

More meaningful NDE measurements can enhance industrial productivity and conserve materials and energy by reducing the rejection rate of manufactured

products. Rejection after processing or machining wastes money and energy. Another important and often overlooked alternative is to use nondestructive testing as a guide in processing to minimize defects caused during fabrication. Still another important factor is the potential reduction in overdesign of products that could be warranted if better methods of determining defects and properties and evaluating performance were available. Such methods could not only save material, but could also provide an intelligent basis for materials substitution.

A relatively new incentive for improved NDE is the specter of product liability. New legislation tends to hold a manufacturer responsible for using state-of-the-art technology in design, production, and inspection insofar as these processes influence the safety of a product. The cost of insurance has gone up by an estimated 250 percent just since 1975, despite the fact that manufacturing and commercial organizations are absorbing more of the burden through self insurance. Manufacturers are beginning to recognize that reliable NDE enables them to make products that are not only safer but often more cost-effective as well. Thus, we see NDE coming into greater use for consumer items such as automobiles, tools, and appliances.

The Office of Nondestructive Evaluation is working with industrial and standardization groups to provide improved NDE measurements. We feel that the broad technical base that NBS is bringing to NDE is contributing to the achievement of that goal. The potential rewards to our Nation's economy and its people are great.

Harold Berger

Harold Berger
Chief, Office of Nondestructive Evaluation
National Bureau of Standards
B312 Physics Building
Washington, D.C. 20234
301/921-3331

Contents

ARTICLES

- 2** **Microwave Measurements on Snowpacks**
Researchers Gather Avalanche and Runoff Data
Special
 - 6** **NBS Budget Request**
FY 1980 Proposal Detailed
 - 10** **Casting Light on Nature's Ways**
Laser-Interferometer Used for Studies on Earth-Motion, Gravity Waves in Space
-

INTERFACE

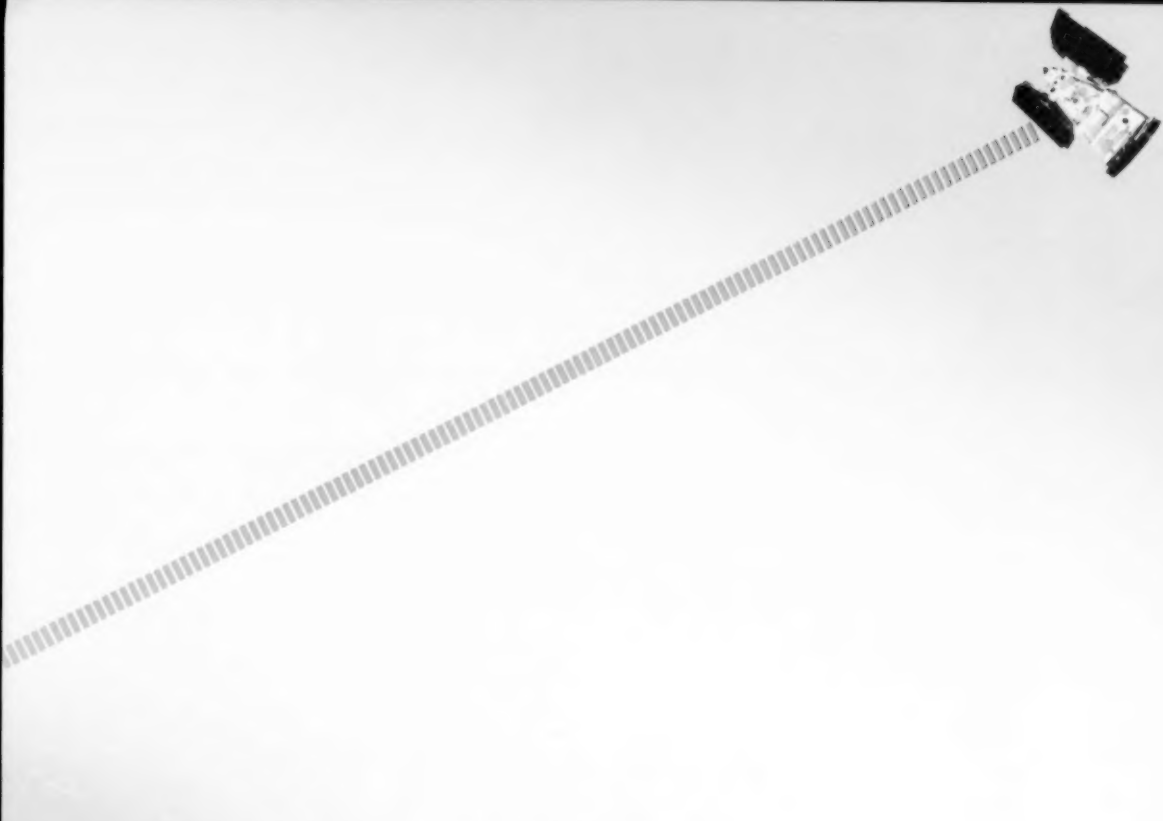
- 14** **ON LINE WITH INDUSTRY**
Measurement Services for Ultrasonic Non-Destructive Evaluation
 - 17** **STANDARD STATUS**
National Load Standard Being Revised
 - 18** **STAFF REPORTS**
X-Ray Image Magnification Technique Developed
Evaluating Pipe Welds
Fusion Diagnostics: Spectrum of Molybdenum Ion Determined
-

UPDATE

- 24** **CONFERENCES**
MITRE/NBS Symposium on Local Area Communications Networks
Conference to Advance Thermal Analysis
Computer Systems Conference
Conference Calendar
 - 26** **PUBLICATIONS**
Teacher Aids
Design Guide for Reducing Noise in and around Buildings
Performance Criteria and Plumbing System Design
NBS Publications
 - 28** **NEWS BRIEFS**
-



Microwave on



by Frederick P. McGehan

THIS year for the third straight winter, scientists from the National Bureau of Standards, Boulder, Colorado, laboratories donned heavy parkas, thermal underwear, mittens, and snowshoes, and left the warm confines of their laboratories for the Rocky Mountains.* Hauling microwave analysis and measuring equipment by toboggan into mountain passes and other "back-country" areas, they have made microwave measurements of the snowpack—measurements that should enable them to tell the composition and moisture content of the snowpack.

McGehan is a writer and public information specialist in the NBS Boulder, CO, Program Information Office.

* See "Measuring With Microwaves," April 1978 DIMENSIONS, page 9.

Measurements snowpacks

turn page

A Technical Look at Snow Measurement

The current emphasis in the NBS snow-measurement program is to use a variety of systems to measure the microwave scattering properties of different snowpack formations (Alpine and modified deposition) in Colorado and California. All measurements are made *in situ* with the snow in its natural state.

A portable (toboggan mounted) Frequency Modulated-Continuous Wave (FM-CW) radar system was developed by NBS researchers to measure and record profiles of snow packs down to ground level. This system was used to monitor changes in snow stratigraphy as a function of time of day. The system is continuously swept in frequency over the bandwidth 8-12 gigahertz (GHz). Snow depths up to four meters have been measured with it.

Two antennas were used in all experiments: one for transmitting the incident signal into the snow and the other to receive the reflected signal. The antennas were mounted side-by-side above the snow's surface. All of the results were obtained with antennas at near normal incidence.

The potential payoff is enormous. If their measurements of moisture content of the snow prove accurate—and the outlook is very promising—then a new tool has been found to give the U.S. Soil Conservation Service and the Bureau of Reclamation more accurate predictions of spring and summer runoffs. This is vitally important in the western United States where approximately half of all irrigation water comes from the mountain snowpack runoff.

Analysis of snow composition can also be a tip-off to impending avalanches. Again, if the NBS scientists' experiments are successful, then a network of microwave sensors connected to a central data-receiving office may be established to warn of avalanche conditions.

The Bureau researchers, members of the Electromagnetic Fields Division, have expanded their moisture experiments to California's Sierra Nevada mountains this year. Snow in the Sierra Nevada range is denser because temperatures are generally warmer than in the Rockies.

"We have had considerable success in measuring the water content of alpine (Rocky Mountain) snow," says Harold S. Boyne, chief of the Electromagnetic Fields Division. Correlation between actual water content and microwave measurements is "within 5 percent," he adds.

"We are somewhat less certain how useful the microwave technique will be for avalanche work. That's at a pretty primitive stage at the moment," Boyne says. This is because the data base does not exist that would correlate the electromagnetic response with instabilities in the snowpack leading to avalanche conditions.

Three other Federal agencies have expressed interest in and support for the NBS work. These are the National Aeronautics and Space Administration (NASA), the Soil Conservation Service (SCS), and the Forest Service.

This year for NASA, the NBS scientists have measured snowpack with radiometers for water content, density, and amount of water on the surface. The radiometers (instruments for measuring electromagnetic radiation) were positioned on stands 15 me-



NBS scientists will present the results of their work at the Western Snow Conference next month in Sparks, Nevada.

ters (50 feet) above the ground. This is part of a NASA feasibility study to determine depth of snowpack in large watershed areas by satellite.

The NBS data will be correlated with measurements taken in the same area and at the same frequencies by radiometers installed in Landsat satellites orbiting high above the earth.

Working in cooperation with the U.S. Forest Service, NBS scientists planted microwave sensors on top of Berthoud Pass (3499 meters or 11 314 feet) about 55 kilometers (35 miles) west of Denver. They have attempted to use the microwave technique to determine the loading (disposition) of the snowpack due to winds and storms. Both of these conditions stress the snowpack to the extent that various layers may shift, making an avalanche likely.

If the microwave method proves sensitive enough, the data will be used as part of a Forest Service model for predicting avalanche activity. Five to 10 microwave sensors may be installed in avalanche-

The snow-measuring program is making news. On location, Harold S. Boyne, chief of NBS Electromagnetic Fields Division, explains the NBS snow measurement work to a Denver television reporter.

prone areas over the next three to five years as a supplement to a network of trained observers, who are often members of ski patrols.

NBS is discussing with the Soil Conservation Service the possibility of placing such sensors at various mountain areas that the SCS has designated for measurement of snowpack water content. Accurate and reliable sensors would relieve SCS personnel from the chore of physically going to these locations, digging a pit, taking a specified amount of snow, and measuring it for water equivalency.

NBS scientists will present the results of their work at the Western Snow Conference to be held next month at Sparks, Nevada. □

NBS BUDGET REQUEST FY 1980

by Sharon Washburn

THE National Bureau of Standards budget request for FY 1980 is \$96 489 000, which includes a \$9 945 000 increase over the FY 1979 appropriation. The recommended program changes, both increases and decreases, are described below. However, the dollar amounts given may not directly correspond to the information in the attached table due to adjustments to base increases also included in the FY 1980 request.

Competence Building to Continue

The Bureau's highest priority is reflected in the \$2 million request in the area of central technical support to continue the process of competence building. Through competence building NBS hopes to maintain and enhance the technical resources of the Bureau, especially in areas likely to require more attention in the future as national scientific and technological priorities and needs change.

Research fields selected for this multi-year program will involve long-term theoretical and experimental studies upon which NBS and its clients can rely for expertise now and in the future. Special competence building initiatives are being undertaken where scientific solutions compatible with the NBS mission appear possible and where the underlying scientific foundation appears ripe for advancement. Research areas chosen for the competence enhancement program include: surface science, non-linear convection and smoke dynamics, organic electrochemistry, small angle neutron scattering, metrology and wave optics, electrotechnology, and experimental fluid mixtures.

Increases in Research and Standards

The largest increase in the Bureau's request is in the area of measurement research and standards: \$4 million to expand the materials durability program, \$500 000 for the regional measurement assurance programs, and \$2 million to increase the recycled materials program.

The expanded materials durability program would focus on the degradative processes that affect the

Washburn is a writer and public information specialist in the NBS Public Information Division.

economic and safe use of the three most important industrial classes of materials—metals, polymers, and ceramics. These degradative processes—corrosion, fracture, wear, and plastic additive migration—result in the deterioration and catastrophic failure of materials and cost the U.S. economy over \$100 billion a year.

With the increased funding, NBS would conduct research into the fundamental chemical processes controlling durability and develop predictive equations for materials performance and lifetime in use. NBS, as the central Federal laboratory for materials research, can provide the basis for the measurement methods and standards needed to reduce these types of materials failure and thereby contribute to economic savings, more efficient resource utilization, and increased public safety.

The increase for the regional measurement assurance programs would permit the development of more efficient dissemination methods to satisfy growing demands for NBS calibration services. These programs are aimed at serving a larger number of customers without a proportionate increase in NBS staff or funding by encouraging a number of laboratories in a region to cooperate in making their measurements traceable to NBS. In such a program, NBS interacts with one of the laboratories, providing a transport standard and guidelines for the measurement system. The laboratories in the group then intercompare their measurements.

The \$2 million increase for the recycled materials program would allow researchers to concentrate on the development of methodology and data needed by communities to recover resources from the 145 million tons of municipal solid waste that are disposed of annually. Researchers would also attempt to characterize potential refuse-derived materials and fuels so they may be substituted for virgin materials whenever feasible. The development and characterization of refuse-derived fuels are key to the economic success of recycling efforts. It is estimated that refuse-derived fuels can supply 2 percent of the nation's energy. This work is mandated by the Resource Conservation and Recovery Act of 1976 (Public Law 94-580).

NBS is requesting an increase of \$1 million in the

engineering measurements and standards area to develop measurement methods for the accurate characterization of the electromagnetic environment. Methods, standards, and data will contribute to the solution of the many electromagnetic interference (EMI) problems affecting the country today and provide the measurement foundation necessary to determine the extent of EMI effects. In addition, it is expected that foreign regulations concerning EMI will affect over \$10 billion of U.S. exports in 1980.

An addition of \$1.2 million to the working capital fund is requested to augment the amount of working capital available for the production of renewal Standard Reference Materials (SRM's), which are well characterized, homogeneous, stable materials or artifacts with specific properties or components measured and certified by NBS. Since the first SRM was issued in 1906, the Bureau has made available over 1000 different SRM's. In FY 1978 alone, NBS distributed 37 000 SRM's to more than 10 000 users around the world. However, the total capital available for SRM production has remained fixed over the last five years in spite of rising costs, and this has resulted in a serious shortage of production capital. The lack of capital already has caused a depletion of stock that has led to serious disruptions for industrial customers.

Funding Decreases

Also included in NBS' FY 1980 budget request are proposals to eliminate or reduce programs by a total of \$5 430 000. It is expected that the impact of these reductions can be minimized through improved NBS cooperation with industry and other agencies or through transfer of the technology to the users.

In the area of measurement research and standards, funding for programs will be decreased by \$1 723 000: fundamental physical measurements and standards (\$212 000), radiation measurements and standards (\$1 008 000), and thermodynamic and molecular science (\$503 000).

In the fundamental physical measurement standards program, further development of portable

The Bureau's highest priority is reflected in the \$2 million request in the area of central technical support to continue the process of competence building.

turn page

An expanded materials durability program would focus on the degradative processes that affect the economic and safe use of the three most important industrial classes of materials—metals, polymers, and ceramics.

Also included in NBS' FY 1980 budget request are proposals to eliminate or reduce programs by a total of \$5 430 000.

NBS Congressional Appropriations (in millions of dollars)*

	FY78	FY79	FY80 (request)
Measurement research and standards:			
Physical and chemical measurements and standards	17.6	16.6	16.6
Materials and thermodynamics measurements and standards	14.0	14.3	18.7
Measurement assurance program	1.5	2.1	2.7
Applied measurement programs	7.9	8.2	10.8
Subtotal	41.0	41.2	48.8
Engineering measurements and standards:			
Engineering standards	2.1	2.1	1.5
Safety and engineering research	5.1	5.0	5.0
Technical support to industry productivity	13.2	14.8	14.2
Mathematical sciences	2.4	2.7	2.9
Fire science and engineering	—	—	1.1
Subtotal	22.8	24.6	24.7
Computer sciences and technology	4.3	11.1	11.5
Cooperative technology	.2	1.6	—**
Central technical support:			
Maintenance of technical competence	1.7	4.5	6.7
Capital transfers and facilities	1.6	.2	.4
Subtotal	3.3	4.7	7.1
Transfer to working capital fund	3.2	3.3	4.4
TOTAL	74.8	86.5	96.5

*All figures are rounded.

**Future of program depends on results of feasibility study, which will be completed in September.

**"This budget request is the result of careful evaluation of all Bureau programs and priorities in the light of anticipated national needs and President Carter's desire to limit Federal spending."—Ernest Ambler
Director, NBS**

Josephson-junction-type electrical standards would be eliminated. Industrial personnel can now make measurements of sufficient accuracy using new commercial instruments that incorporate these standards.

The proposed reductions in the radiation measurements and standards program would curtail the neutron cross-section standards project and selected services in spectrophotometry and radiometry. The most recent major outputs of the neutron cross-section standards project have been directed toward improving a data base maintained for the Department of Energy (DOE). DOE has agreed to fund the major portion of this work. In the spectrophotometric and radiometric areas, the traditional methods of assuring measurement accuracy through calibration services would change to systems that rely on interactive, participatory user roles. For example, in the early stages of development are a research associate program, which would be sponsored by the Council on Radiation Measurements, and a measurement assurance program for spectral diffuse reflectance and retroreflectance.

In the thermodynamic and molecular science program, funding for studies of the effects of ultraviolet radiation on molecules, development of improved methods for measuring the energetics of chemical reactions, and improvements in the methods and data base for mass spectrometry would be decreased. These projects have provided the data needed to define the technical options for regulatory decisions and can now be reduced in scope.

In the engineering measurements and standards area, funding would be reduced by \$3 707 000 encompassing six programs: engineering standards (\$730 000), building research (\$240 000), consumer product technology (\$165 000), electrotechnology (\$162 000), mechanical engineering and process technology (\$482 000), and field methods (\$1 928 000).

The funding cut in engineering standards would result in reductions in several areas. Centralized engineering standards management would be eliminated. As a result of the recent NBS reorganization, NBS can adequately monitor and coordinate the program without permanent centralized con-

trol. Several efforts in the development of laboratory evaluation methodology would be combined under the Voluntary Laboratory Accreditation Program. This approach will permit testing of these techniques in a realistic setting. The collaborative reference program would be discontinued as this work has reached the point where it can be supported and carried out by the private sector.

Since the building materials industry and private testing laboratories now have the capability and expertise to develop test methods and standards for building materials and composites, NBS would discontinue further development of these methods. Specialized needs can be supported by other agencies as necessary.

The consumer product information labeling program would be eliminated because the effort required to promote the program in industry is far greater than anticipated and available test methods are not adequate for consumer labeling of some products.

Funding for the electrotechnology program in electromechanical transducers, which is primarily concerned with characterizing these devices in extreme environments, would be eliminated. This work is of interest mainly to the Department of Defense, which can fund future work in this area as needed.

NBS would curtail the mechanical engineering and process technology program in the areas of audiometry and environmental noise measurements because they fall within the purview of other government agencies. NBS would also reduce support for further design of calibration procedures for cryogenic fluid meters as this work has advanced to the stage where it can be assumed by industry or an industrial association.

Reduction of the field methods program stems from a redirection of the project based on experience gained from participation in the President's Domestic Policy Review on Innovation. □

It is expected that the impact of program reductions can be minimized through improved NBS cooperation with industry and other agencies or through transfer of technology to the users.

Casting Light on Nature's Ways



by Frederick P. McGehan

JULIUS Erving, a noted basketball player with the Philadelphia 76'ers, is known as the "Doctor of the Dunk" for his accuracy in stuffing basketballs through hoops.

Judah Levine, a physicist with the National Bureau of Standards in Boulder, Colorado, might similarly be called the "Doctor of the Earth" for his accuracy in measuring the minute stresses and strains this planet undergoes. In a sense, Levine has spent the last 10 years taking the earth's pulse with a sophisticated light-producing and light-measuring stethoscope designed by NBS researchers. By doing so, he has discovered some new facts about the nature of our planet, developed an idea for a portable earthquake-predicting device, and, more recently, turned his attention toward answering some esoteric questions about the stars.

Most of Levine's 10-year story took place 60 meters underground, in a 30-meter long tunnel of

an abandoned gold mine near Boulder. It was there that he set up a laser capable of producing highly homogeneous (stable) wavelengths of light and directed the light through a very long interferometer—a laboratory measurement device based on the interference of waves, mainly light waves.*

The NBS laser/interferometer, designed by NBS researchers in 1961 and dismantled over a year ago, was one of the most sensitive earth-movement detectors (seismometers) ever developed. It could detect vibrations as small as 5×10^{-13} meter in amplitude, which amount to jiggles no larger than 20 trillionths of an inch. And it could measure these changes whether they occurred as fast as 100 times a second or as slowly as one time per year.

Optical Interferometers

Levine says of the NBS system, and of all optical interferometers, "Basically, it's a case of taking a beam of light down a path, splitting it into two or

McGehan is a writer and public information specialist in the NBS Boulder Program Information Office.

* There are acoustic as well as optical interferometers.

more parts, bouncing it back and letting it interfere with itself [letting the parts of the original beam recombine]." Changes in self-interference carry the information needed for making measurements. In very simple terms, self-interference (or recombination of the broken-up parts of an original single beam) might be compared to two or more columns of a marching band reuniting into a single column. If all members are marching at the same speed, and all have performed their maneuvers properly, all units will be "in phase" as they recombine. If one unit or more units are out of phase, the differences will be detectable. (See box.)

Self-interference can be used to study light, as an adjunct to microscopy studies, or to measure distance.

"The interferometer as an instrument for measuring wavelengths of light was used for many years almost exclusively by national laboratories to fix national length standards," says Levine. "Its high cost prohibited it from being used routinely for length measurements."

Gradually, Levine notes, there came the realization that the interferometer could be used as a tool to obtain relative—rather than just absolute—length measurements. In other words, it was not always important to know only the absolute distance between two fixed points. It could be important to know *changes* in distance between points. This information on relative effects would be valuable in obtaining new knowledge about the earth, including earth-tide movements and the interaction between the earth's molten core and the mantle.

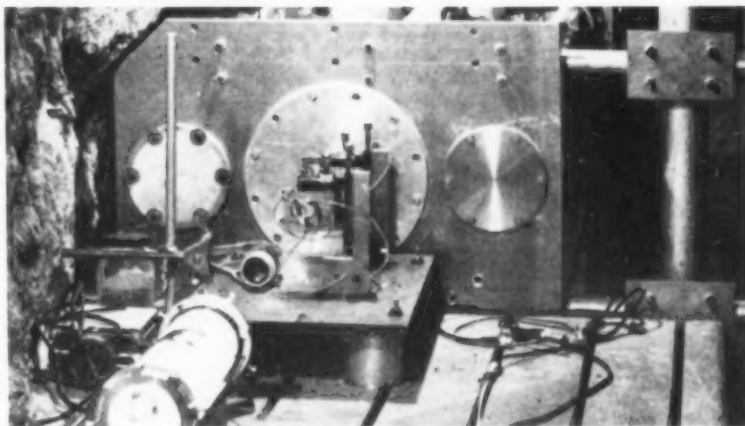
Until 10 years ago, there was a problem of making the wavelengths of light stable enough to measure relative effects. The development of the krypton lamp provided enough stability for international agreement on a definition of the meter in terms of wavelengths of light, but it was not sufficiently stable for the extremely sensitive measurements of earth motions.

NBS Laser/Interferometer

It was an accomplishment of John L. Hall, an NBS physicist with the Joint Institute for Laboratory Astrophysics* in Boulder, and Richard L. Barger, a physicist in the NBS Time and Frequency Division, that resolved the stability problem. "By continuously tuning a laser so as to maximize the absorption of its radiation in some molecule, you can build a laser that is incredibly stable," says Levine. Using methane molecules for the stabilizer and a mixture of helium and neon for the active medium, Hall and Barger built what is known as a saturated absorption stabilized laser. This technique stabilizes the laser frequency and wavelength to one part in 10^{11} or 10^{12} (up to one part in a trillion).

Levine took that highly stabilized laser and used it as the light source for an interferometer system he anchored to bedrock in the abandoned gold mine. This gave him the stability needed to detect

the minute movements and changes in length produced by shifts within the earth. In order to measure the long-term stresses and strains, it was necessary that the laser strainmeter be operated at the same site for a long period of time. This assured that movements produced by local topographic conditions could be measured and subsequently eliminated. One of the first things Levine measured was earth tides.



Earth Tides

Although the existence of earth tides has been known for some time, a precise comparison between theory and observation had been lacking. Earth tides are produced by changes in the gravitational attraction of the sun and the moon as the earth both turns on its axis and moves in its orbit around the sun. These tides are cyclic motions that can result in peak vertical displacements of 30 centimeters or more. Levine's observation in Boulder and similar observations by a colleague, Jon Berger of the University of California at San Diego (who has three 800-meter-long interferometers on the surface) showed that uncorrected observed tides were within 10 to 20 percent of theoretically predicted tides. Some of the discrepancy is due to the effect of the ocean. There are also corrections that Levine had to make due to local topography and local inhomogeneities in the earth's crust.

Having obtained corrected data on the earth-tide effect, Levine used this as a baseline for additional studies of the earth. "The response of the earth to a known signal tells you a lot about the earth," he notes.

Like a child's swing or any mechanical system, the earth has a resonance—a frequency that the system wants to maintain. It had been theoretically predicted that the interaction of the earth's liquid core with the outer mantle would give rise to a resonance of about one cycle per day. Levine was able to confirm this by using earth-tide observations.

In another example of earth-tide measurements being used as a baseline for other investigations, Levine was able to cast further doubt on a much challenged theory that there is a preferred direction in space for gravity. For this to be true, Levine says, there must be change in the earth tides through

Almost the full length of the NBS strain meter can be seen in the photograph on the opposite page. Here, at the other end of the laser/interferometer, is one of the two helium-neon lasers used with the system. Located in the tunnel of an abandoned gold mine, the device generated data on movements within the earth.

* The Joint Institute for Laboratory Astrophysics is cosponsored by NBS and the University of Colorado.

turn page



Entrance to the Poorman gold mine near Boulder, Colorado, where Levine's laser/interferometer operated for nearly ten years.

the lunar month as the moon-earth orientation changes with respect to the theoretically hypothesized preferred direction. But when Levine looked at the appropriate tidal components, he found the values to be within a few percentage points of what had been expected from the classical theory, which does not posit a preferred direction for gravity. If the preferred direction exists, "It produces a very small anomaly," he notes.

Predicting Earthquakes

Perhaps of greatest interest to most people is the relationship between Levine's work and the prediction of earthquakes. By keeping his scientific stethoscope to the earth for so long, Levine was able to detect unanticipated phenomena such as shifts and other movements in the earth's crust as the result of distant earthquakes or underground nuclear explosions in the Nevada desert. He compared his data in the seismically inactive Boulder region with Berger's data in seismically active southern California. Whether laser strainmeters can be used routinely to forecast earthquakes is unclear at this point. In order to evaluate their potential utility, additional measurements must be made in seismically active areas.

Because of atmospheric disturbances, such as turbulence, laser strainmeters have to be enclosed in vacuum pipes and are often located in mines or abandoned railroad tunnels. The complexity of the installation makes it difficult to find suitable sites.

Therefore, Levine is constructing a portable laser strainmeter that will use three—instead of one—wavelengths of light at the same time. By comparing the differences among the three wavelengths, Levine is hoping to be able to detect those changes caused by atmospheric conditions and eliminate

them from the final calculations. If he is successful, he will also be able to eliminate the use of a vacuum pipe and measure over longer distances—up to 50 kilometers. The distance now is limited by the size of the enclosure.

There exists the possibility of utilizing a network of laser strainmeters as early warning devices for earthquake-prone areas. Levine believes this network may be useful in detecting a certain class of earthquake, but that even if the technique proves accurate, it would be too expensive to install enough permanent strainmeters to detect very localized strains and stresses. The portable strainmeter, however, could provide substantially the same information at much less cost. Also, with its long-distance capability the portable device might be useful to the U.S. Coast and Geodetic survey for map-making purposes, Levine notes.

Studying Stars

There is another aspect to Levine's work that deals neither with the earth's surface nor its core. This aspect is found in the stars.

Levine has used the earth as a detector in a search for gravitational waves radiating from certain stars. In theory, such waves would induce slight strain fluctuations when they strike the earth; these fluctuations could be measured by the highly sensitive laser strainmeter.

The theory of relativity postulates that there are gravity waves propagated in space that travel with the speed of light. At least one scientist has constructed a huge aluminum antenna and claims to have detected gravitational waves from outer space, possibly emanating from super nova explosions.

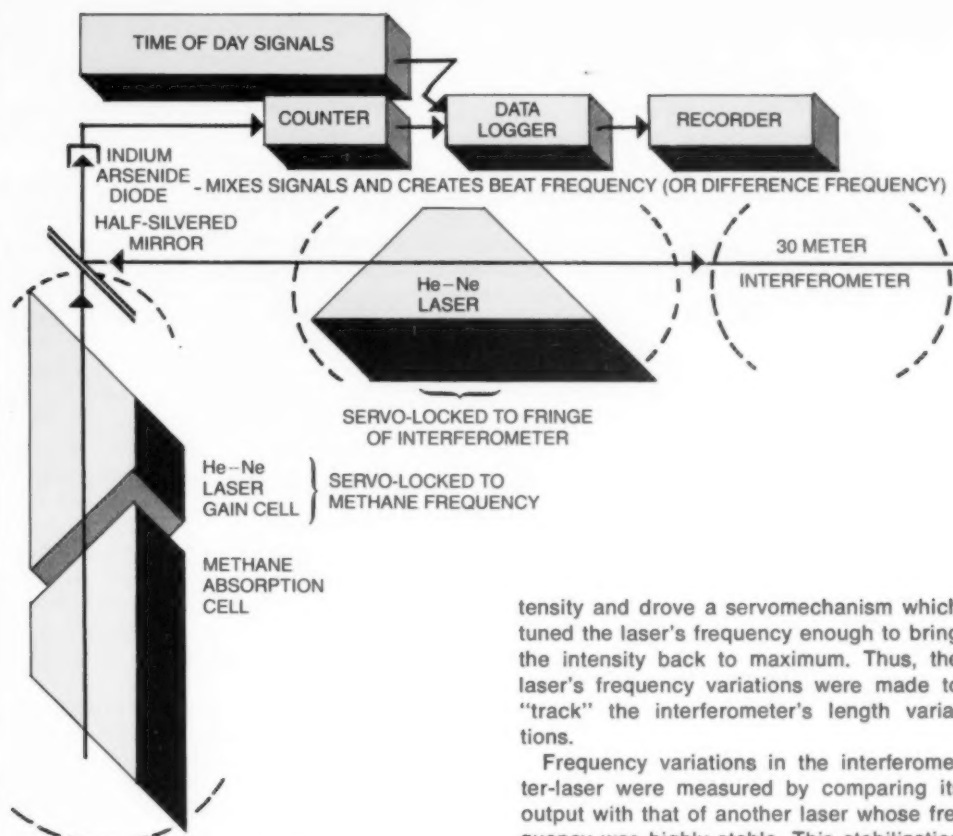
Levine has used the laser strainmeter to look for gravitational waves from pulsars and rotating binary stars. Pulsars are stellar objects perhaps 10 kilometers in diameter that emit periodic pulses of electromagnetic energy. They are expected to radiate gravitational waves as well. Levine was unable to detect gravitational waves emanating from the Crab pulsar because the signal produced by the gravitational waves was masked by "noise" produced by atmospheric turbulence and other man-made sources.

Because of their low frequency, rotating binaries—two separate stars that rotate around their center of mass—"probably provide the most favorable experimental situation," Levine says. But even here the so-called background noise has to be overcome. A prime source of this background interference, Levine found, is fluctuations in barometric pressure on earth.

He says, "the most promising possibility for the detection of gravitational waves at the moment seems to require flying the detector in space. It appears that earth-bound detectors will always be limited by various terrestrial noise sources."

It also appears that in the future Levine may be forsaking a unique subterranean career for a unique sally into space exploration. □

NBS SEISMOGRAPH: Technical Brief



In the quiet, stable environment of an abandoned gold mine, a laser/interferometer seismograph developed by researchers at the National Bureau of Standards generated data for over 10 years on infinitesimal vibrations of the earth's crust.

The seismograph comprised two independent helium-neon lasers run simultaneously: one to sense the variation in length of the interferometer and the second to serve as a standard of frequency/wavelength for comparison with the first.

The interferometer was an adaptation of the Fabry-Perot device. The intensity of infrared laser light transmitted through its partially transmitting mirrors emerged from the other end as a periodic function of the distance between the mirrors. Maximum intensity was obtained whenever the mirrors were separated by an integral number of half-wavelengths. If the mirror separation varied with time, as when the mirrors were moved by vibrations in the earth's crust, then the intensity varied.

A photodiode sensed this variation in in-

tensity and drove a servomechanism which tuned the laser's frequency enough to bring the intensity back to maximum. Thus, the laser's frequency variations were made to "track" the interferometer's length variations.

Frequency variations in the interferometer-laser were measured by comparing its output with that of another laser whose frequency was highly stable. This stabilization was accomplished by locking the second laser's output to the constant frequency of a saturated absorption line in methane gas. Frequency fluctuations in this stabilized laser amounted to less than few parts in 10^{12} , though this is not the ultimate stability one could expect from this type of device.

Both lasers, oscillating at about 3.39 micrometers, were focused onto an indium arsenide diode which mixed the signals and created beat frequencies. One of these, the difference signal, was filtered out and recorded along with time-of-day signals. This difference signal was equal to the interferometer frequency minus the stabilized frequency, and it varied in frequency according to the variations in length of the interferometer. Sensitive enough to detect vibrations in the earth that changed the interferometer spacing by only a few parts in 10^{12} , the system was also fast enough to record such changes at frequencies up to 50 cycles per second, while retaining the stability to measure vibrations at frequencies of less than one cycle per year.

MEASUREMENT SERVICES FOR ULTRASONIC NON-DESTRUCTIVE EVALUATION

by Donald G. Eitzen

Acoustic emission and pulse/echo ultrasonic techniques offer great potential for detecting and evaluating materials defects nondestructively. However, these methods are sensitive to measurement system characteristics and to the condition of the reference artifacts used. An effort to improve the reliability and diminish the uncertainty of these techniques is underway at the National Bureau of Standards. Part of this effort has focused on the development of measurement services for transducers and reference blocks. The measurement services now available from NBS are described below:

1. *Ultrasonic Transducer Power Output Versus Frequency.* By using a modulated radiation pressure technique, the absolute total power output of ultrasonic transducers versus frequency is measured over any part of a range from about 1–20 MHz. The uncertainty is frequency dependent but is nominally about ± 5 per-

cent. In addition to this frequency information, the measurement provides the value of the radiation conductance used to calculate absolute power output levels. The apparatus, procedure, error analysis and results are discussed in *Ultrasonic Transducer Power Output by Modulated Radiation Pressure* by Greenspan, Breckenridge, and Tschiegg, *J. Acoust. Soc. Am.*, 63(4) (Apr. 1978).

2. *Ultrasonic Transducer and System Power Output by Calorimetry.* By using a twin, series flow ultrasonic calorimetric comparator, the time-averaged total absolute power output of a transducer or system is measured for any voltage input waveform in the range of 1–15 MHz. The uncertainty is approximately ± 7 percent. The system, procedures, and uncertainties are described in *Ultrasonic Calorimeter for Beam Power Measurements* by Zapf, Harvey, Larsen, and Stoltenberg, NBS TN 686 (1976).

3. *Aluminum Ultrasonic Reference Block Calibration.* Sets of ASTM E-127 type ultrasonic reference blocks are compared with an interim reference block and associated model by using a well-characterized measurement system. The service provides a mechanism for comparing sets of blocks with the NBS data base and with other reference blocks through the NBS ultrasonic system. The system and detailed procedures are described in *Procedures for the Calibration of ASTM E-127-Type Ultrasonic Reference Blocks* by Chwirut, Sushinsky, and Eitzen, NBS TN 924 (1976).

4. *Loaner Services for Transducers and Reference Blocks.* By arrangement, carefully characterized ultrasonic source transducers and aluminum reference blocks can be made available for loan. These can provide on-site calibration with the user's system. By using the accurately measured calibration ultrasonic source transducers, a user's power or frequency measurement system can be calibrated *in situ*.

The loaner aluminum ultrasonic reference blocks, which have been carefully compared with the NBS interim reference standards, provide a means for users to compare their reference artifacts with those of NBS on their own ultrasonic system.

Additional work on ultrasonic measurement systems is in progress. An expansion of the NBS artifact system for ultrasonic reference blocks to steel and titanium reference blocks is being developed. The feasibility of developing improved steel and titanium reference blocks is to be established in 1979. Also under consideration are material-independent reference blocks made of amorphous, low-attenuation material; these could replace much of the present multiplicity of reference artifacts.

The influence of changes or adjustments to instrumentation on the variations in the amplitude of response from reflectors has also been studied in some detail. For example, changes in the pulse length adjustment of a flaw detector result in amplitude response changes from a reference block by over 13 percent, even after normalization. A study of the effects of different (but very similar) transducers was also conducted (*The Evaluation of Search Units Used for Ultrasonic Reference Block Calibrations* by Chwirut and Boswell, NBSIR 78-1454). The study showed variations of over 26 percent in response due to different transducers. This study has important implications; one of the key issues is: what are the necessary tolerances on the instrumentation in order to obtain the required reliability and uniformity in ultrasonic non-destructive evaluation (NDE)?

Another important area of study is the development of methods for determining the directivity pattern of ultrasonic

Dr. Eitzen is the leader of the Ultrasonic Standards Group in the Mechanical Processes Division of the NBS Center for Mechanical Engineering and Process Technology. For further information contact: Eitzen, B106 Sound Building, NBS, 301/921-3646.

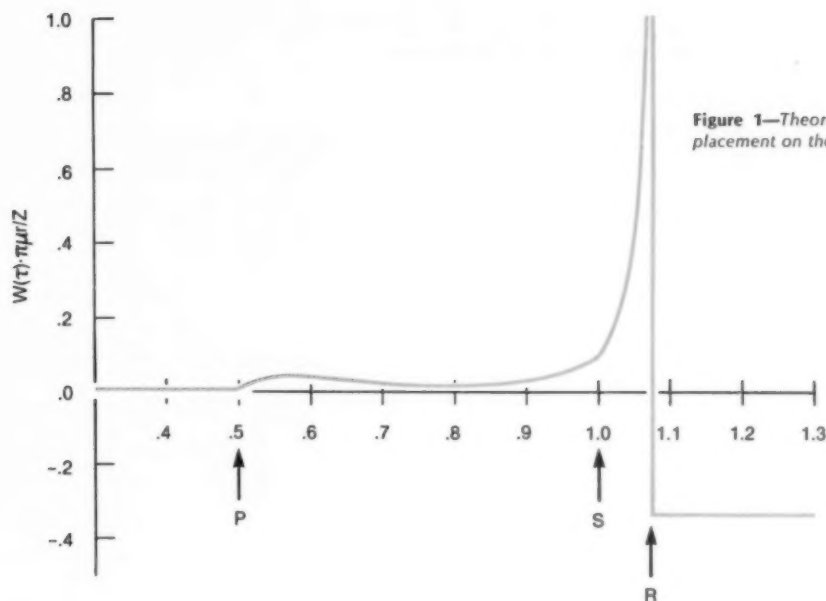
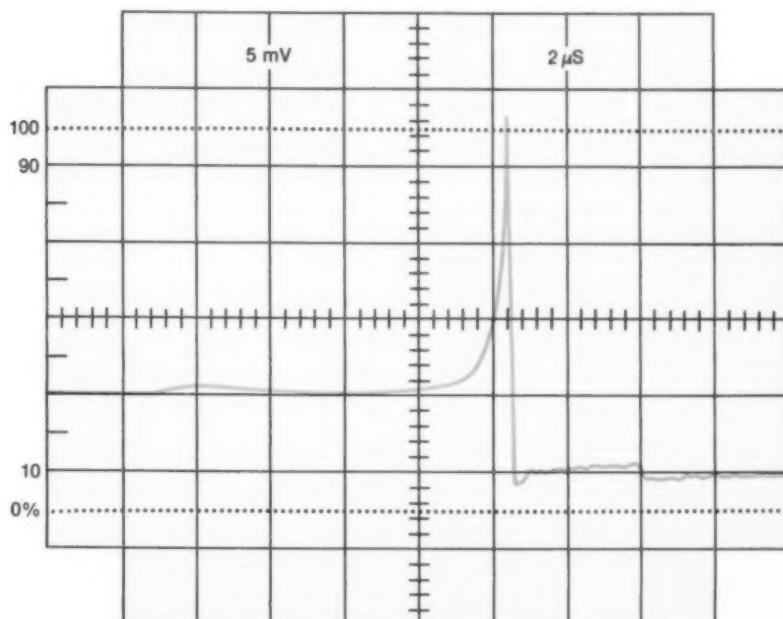


Figure 1—Theoretical waveform of vertical displacement on the transfer block.

$$\tau = ct/r$$

Figure 2—Displacement of transfer block measured with model 1 NBS transducer. New NBS transducer gives even better agreement (not shown) with theory.



transducers. A mathematically well-founded method called planar scanning is being developed as a laboratory method. It is capable of determining all of the important field point parameters of transducers. Work is also proceeding on the development of techniques more appropriate for the user community.

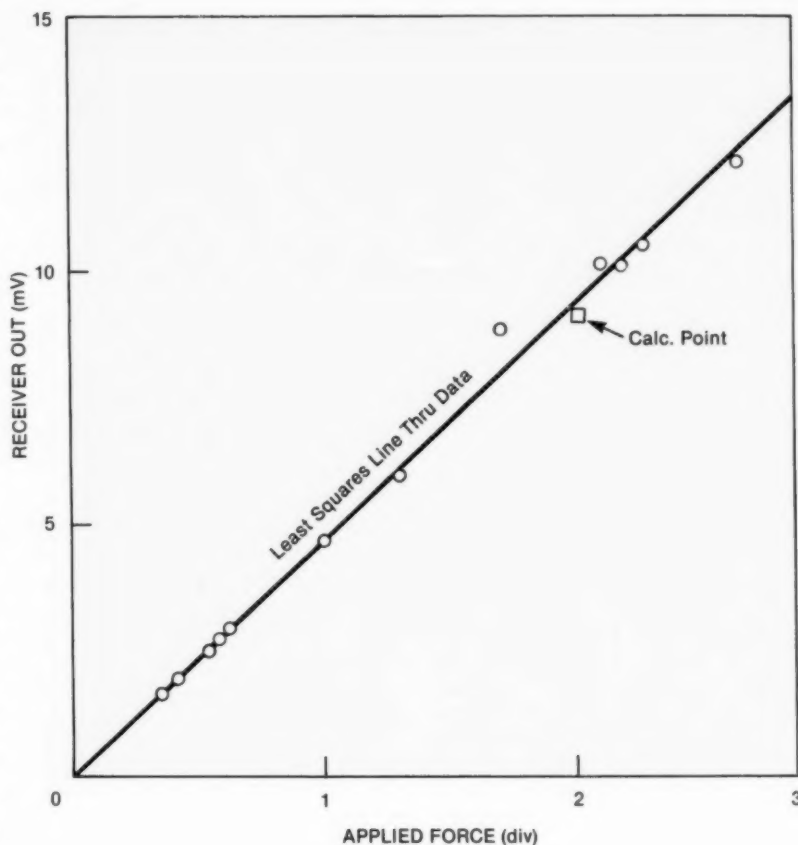
A calibration capability is being developed for acoustic emission (AE) transducers and will shortly be offered as a measurement service. This activity is partially supported by a larger EPRI/NBS Acoustic Emission Program and by the Office of Naval Research. The objective

turn page

is to determine the sensitivity versus frequency of AE transducers over the approximate range of 100 to 1000 KHz. This is accomplished by obtaining time histories from the transducer under test and the NBS standard transducer both mounted on a large (2200 kg) steel transfer block. The input is a simulated source on the same surface of the block as the transducers. The resulting time histories are digitized and processed in frequency space to obtain the desired measure of spectral response. The simulated source and transfer block produce a vertical surface displacement that is theoretically calculable (Figure 1). The displacement measured by the first candidate standard transducer is shown to faithfully reproduce the actual displacement as shown in Figure 2. A newly designed and constructed standard transducer has resulted in further accuracy; it provides measurements of dynamic absolute displacement of the order of a nanometer with an uncertainty of about 3 percent (Figure 3).

There is also a substantial, associated theoretical effort. Theoretical developments using the scattering matrix description of electroacoustic transducers have impacted work on determining directivity patterns of transducers. Two recent theorems on the nature of the radiated field of generalized acoustic sources suggest future calibration techniques for users. A recent theoretical description, which more accurately describes actual transducers, is making possible more realistic standards procedures (NBS and ASTM). Theoretical developments in dynamic elasticity are making possible the development of primary and secondary acoustic emission calibration methods.

Figure 3—Plot showing about 3 percent agreement in dynamic surface displacement between theory and measurement using new NBS standard transducer.



STANDARD STATUS

NATIONAL LOAD STANDARD BEING REVISED

by Mat Heyman

New information on building technology and loads research is being incorporated into ongoing revisions of the American National Standard A58, Building Code Requirements for Minimum Design Loads in Buildings and Other Structures (ANSI A58.1-1972).

According to the secretary of Committee A58, Dr. Bruce Ellingwood of the National Bureau of Standards Center for Building Technology, balloting on the revisions will begin in 1979. The updated standard is scheduled to be published in 1980 after being affirmed through the voluntary consensus approval process established by the American National Standards Institute.

It is expected that revisions to the standard made after 1980 will be able to take into account a new approach to structural design already being worked on by the A58 committee. The new approach is viewed as likely to encourage designers to be more conscious of safety and serviceability aspects of design while making more economical building designs possible.

The A58 load standard specifies magnitudes of loads which might be encountered, but does not address the more general problem designers confront of how loads should be utilized. In fact, there are several common approaches to design practiced in the United States.

These include: allowable stress design for masonry, timber, and steel structures; plastic design of steel frames; and ultimate strength design of reinforced concrete structures. In each of these approaches, the A58 standard loads are handled differently in performing the design calculations.

This diversity generally complicates the process. The calculations frequently do not relate to a meaningful "limit state," a condition where the structure fails to achieve its intended purpose in some way—by collapse or excessive deflection, for instance. Moreover, the randomness in many of the factors which affect structural performance is not handled consistently.

To remedy this situation, the A58 Load Factors Subcommittee is developing general loading criteria suitable for use with different construction materials and technologies. The concept of "probabilistic limit states design" is the basis for this more unified design approach. In addition to the load magnitudes specified in the current standard, these criteria spell out load combinations and probabilistically derived load factors to ensure acceptable performance.

This new approach is expected to bring with it several significant advantages for both the designer and the building owner/occupant:

1. It encourages the designer to be more aware of safety and serviceability aspects of design.
2. It improves the designer's feel for loads and structural behavior.
3. It simplifies the design process by encouraging the same design philosophy to be adopted for all materials of construction.

4. It is a tool for exercising judgment in non-routine design situations.

5. It provides a means for updating codes and standards nationally.

6. It makes more economical designs possible by reducing and controlling the present large range of reliabilities associated with various designs.

Ongoing work on steel, reinforced concrete, masonry, and timber structures indicates that the new criteria need not make structural design more difficult. The format will be familiar and relatively easy to use, with only the basis for determining the load factors changing.

Guidelines for loads and general design which incorporate the new approach are expected to be published early in 1980. These guidelines will recommend specific loading criteria for use with all construction materials and will describe how resistance criteria may be selected in order to be consistent with the loading criteria.

For further details about the new structural design approach or the A58 standard revision, contact Dr. Ellingwood at the National Bureau of Standards, Center for Building Technology, Washington, D.C. 20234. NBS, which holds the Secretariat for the A58 committee, is coordinating the overall effort to update and improve the A58 standard.

Heyman is a writer and public information specialist in the NBS Public Information Division.

COVER STORY:

NBS researchers have developed a technique which makes it possible to magnify an x-ray beam containing information on the structure of an object before it reaches a detector.

X-RAY IMAGE MAGNIFICATION TECHNIQUE DEVELOPED

Certain limitations in the nondestructive evaluation technique of radiography may be overcome by use of a method developed at the National Bureau of Standards for magnifying x-ray images.

Masao Kuriyama, W. J. Boettinger, and H. E. Burdette, Metal Science and Standards Division, A153 Materials Building, 301/921-2986.

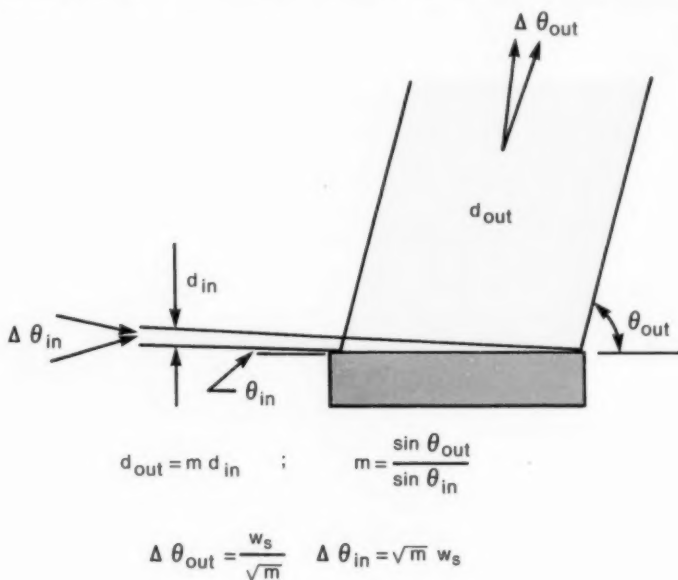
Industrial applications of radiography presently demand the early, real-time detection of small flaws such as tight cracks in materials. Live unmagnified images of flaws or structures are usually recorded or viewed on a detector (an electro-optical imaging system). In order to detect small objects, an improvement in the resolution of real-time imaging systems is required, hopefully without loss of image brightness. However, attempts to improve the resolution usually result in a significant loss of intensity. Thus, the detectability

(or intensity sensitivity) of small signal changes caused by flaws will be lost due to lack of brightness. Any effort to improve resolution for real-time imaging always encounters two opposing problems; if one improves the resolution, then the brightness generally decreases, and vice versa. Present commercial image intensifiers have resolution limits determined by the multistage configuration and the fiber diameter in fiber optic plates. They may be about 50 μm , down to 10 μm at best.

We have developed a technique which enables us to magnify an x-ray beam containing structure information (radiographic or topographic images) before it reaches a detector. This magnification capability can be used either to improve the overall resolution of existing x-ray radiographic techniques which are limited by the detector, or to permit the use of less complex (and high gain) imaging systems to attain resolutions already possible.

In our demonstration, an x-ray magnifier displayed a detailed image of 1000 mesh gold grid (25 μm spacings) with

Figure 1—Asymmetric Bragg diffraction showing one-dimensional magnification of an x-ray beam. The cross-section of the incoming beam, d_{in} , is magnified by a factor, m , to produce the outgoing beam d_{out} . The extremely narrow divergence of the outgoing diffracted beam created by dynamical diffraction guarantees the faithful magnification of x-ray images present in the incoming beam.



good contrast on a real-time basis on an ordinary image intensifier of 100 μm resolution. In order to magnify an x-ray beam which contains structure information (such as one containing radiographic images), the beam is successively diffracted from two silicon crystals. The first diffraction magnifies the beam horizontally and the second in a perpendicular direction.

This magnification technique makes use of Bragg diffraction from a nearly perfect silicon crystal free from dislocations. This type of Bragg diffraction, often called *dynamical diffraction*, has unique features which are essential for making x-ray image magnification possible. When x-ray beams are diffracted from the surface of a crystal and the diffracting planes are not parallel to the crystal surface, the diffraction is termed *asymmetric*. There are three aspects of asymmetric dynamical diffraction which are important for the x-ray magnifier: beam magnification, reflectivity, and the acceptance angle for the diffraction. Figure 1 shows schematically the asymmetric diffraction geometry.

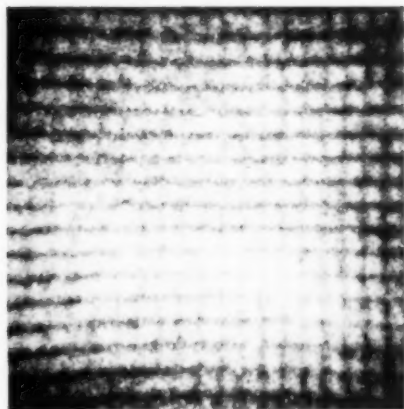


Figure 2—Radiograph taken from image intensifier of a Au mesh with 25- μm spacing using the x-ray magnifier. Original x-ray magnification 25 times.

An incident parallel monochromatic beam of x-rays is magnified in one dimension by a factor m as shown in Figure 1, where θ_{in} and θ_{out} are the angles between the crystal surface and the incoming and outgoing beams respectively. Obviously, high magnifications are obtained when θ_{in} is very small. The "quantum" efficiency of an x-ray magnifier is determined by reflectivity under Bragg conditions. The ratio of the diffracted total flux (photons/second) to the incident total flux is called the reflectivity and is a function of the deviation from the Bragg condition. For a thick, perfect crystal with negligible absorption, this ratio is unity for a range of angles centered about the Bragg condition and falls to zero rapidly for larger deviations from the Bragg condition. Because the reflectivity is unity regardless of the diffracting plane, the intensity (photons/second cm^2) of a parallel beam magnified in one dimension by asymmetric diffraction from a perfect crystal is decreased by a factor $(1/m)$ only because of the magnification of the beam area. Since refractive indices for any materials cannot be larger than one for the ordinary x-ray energy range, the unity reflectivity is the highest efficiency (that is, no loss), which one can expect in x-ray optics. As shown in Figure 1, the maximum divergence of the outgoing beam, $\Delta\theta_{out}$, is related to the quantity ω_H , which is determined by the crystal property of silicon, and is of the order of 6 arc second. This small value of θ_{out} guarantees the one-to-one correspondence of the details between the unmagnified images and the magnified images.

EVALUATING PIPELINE WELDS

The Department of Transportation is sponsoring work at the National Bureau of Standards on the inspection and evaluation of girth welds of the kind used in cross-country pipelines for oil and gas.

Leonard Mordfin, Office of Nondestructive Evaluation, B312 Physics Building, 301/921-3331.

Recent advancements in nondestructive evaluation (NDE) and fracture mechanics have led to a widely held contention that the existing quality standards for pipeline welds are too stringent. In particular, the contractor for the now-completed Trans-Alaska Oil Pipeline asked the Department of Transportation to waive these standards for a substantial number of defective welds on the grounds that a fracture-mechanics analysis showed that they would not diminish the performance of the pipeline. Acting in a consulting capacity to the Department's Office of Pipeline Safety Operations, NBS evaluated the technical merits of the waiver request. This proved to be a difficult task because the contractor's application provided insufficient data for a rigorous assessment.

In order to provide a more efficient procedure for future evaluations of this type, the present NBS effort is designed to furnish DOT with some of the technical information it would need to establish guidelines governing the content of such waiver requests.

The NBS effort has both fracture-mechanics and NDE components. In the former, experimentally verified fracture-mechanics models and other predictive approaches for pipeline girth welds are being developed in order to identify the

turn page

kinds of data needed to properly assess the performance of flawed welds. The NDE part of the work seeks to identify the kinds of radiographic information which are needed to properly assess defect dimensions, and will also develop improved inspection procedures (radiographic and ultrasonic) that will enhance the characterization of weld defects.

This three-year project was initiated in February, 1978, and substantial progress has been achieved. Literature surveys and test method evaluations are underway. The most visible results involve the fabrication of girth welds, containing intentional defects of various kinds, in full-scale pipe of a commonly used type. These welds have been inspected radiographically and ultrasonically and will be cut into laboratory-sized samples for mechanical testing evaluations.

Within the past several months, discussions with DOT indicate that the program will be expanded to emphasize the new gas pipeline to be built from Alaska through Canada to the lower 48 states.

FUSION DIAGNOSTICS: SPECTRUM OF MOLYBDENUM ION DETERMINED

The spectra of highly ionized molybdenum atoms have been of considerable interest lately because of their appearance in controlled thermonuclear research plasmas. The 13-times ionized molybdenum ion (Mo^{13+}) is especially useful for plasma diagnosis because it has a simple spectrum, with the total emitted intensity concentrated in just a few lines. Researchers at the National Bureau of Standards have observed the spectrum of Mo^{13+} with a low-inductance spark and a laser-produced plasma in the region from 7 to 63 nm on the 10.7-meter grazing-incidence spectrograph at NBS. From the identification of 35 lines, a system of 22 energy levels has been determined.*

Joseph Reader, Gabriel Luther, and Nicolo Acquista, Atomic and Plasma Radiation Division, A153 Physics Building, 301/921-2011.

Mo^{13+} is a member of the copper (Cu) singly ionized isoelectronic sequence; the ground configuration is $3d^{10}4s$, and the excited configurations are all of the type $3d^{10}n\ell$.

Recently we observed the 4s-4p resonance lines of the six copper-like atoms Rb^{7+} — Mo^{13+} in a low-inductance spark. These observations confirmed the reported identification of the Mo^{13+} resonance lines in tokamak plasmas. We have now greatly extended our observations and have carried out a complete analysis of the Mo^{13+} spectrum.

* See pages 25, 26 of June 1977 *DIMENSIONS*.

Figure 1—Nd/glass laser used for NBS experiments. The laser has a power of 3×10^6 W.



The Experiment

The spectra were excited in two different light sources. The first was low-inductance open spark. In this source, the spark takes place between metallic electrodes in vacuum after being triggered by a high frequency discharge from a third electrode. We used capacitors of either 4.7 or 14.2 μF at voltages varying between 1 and 15 kV.

The second source was a laser-produced plasma. This was obtained by focussing the light from a Nd/glass laser (wavelength 1.06 μm) onto a flat metallic target. The focussing lens was a two-component system having an effective focal length of about 70 mm. The geometrical arrangement is shown schematically in Figure 2. The diameter of the focal spot at the target was about 200 μm . Typical laser pulses had an energy of 15 J and a duration of 10 ns.

The spectra were recorded on our 10.7-m grazing-incidence spectrograph. The grating had 1200 lines/mm, providing a plate factor of .025 nm/mm at 30 nm. The angle of incidence was 80°.

The ionization stages of the observed lines were distinguished in several ways. First, the spectra were compared with spectra taken with a low-voltage sliding spark. Our previous work showed that the sliding spark would not produce atoms of Mo ionized more than about eight times. Second, the variation of line intensity with spark voltage was observed. We found that the spectrum of Mo^{13+} was not significantly excited at voltages below 3 kV and showed practically no enhancement at voltages above 3 kV. Third, the spectrum of the low-inductance spark was compared with the spectrum of the laser-produced plasma. The laser-produced

turn page

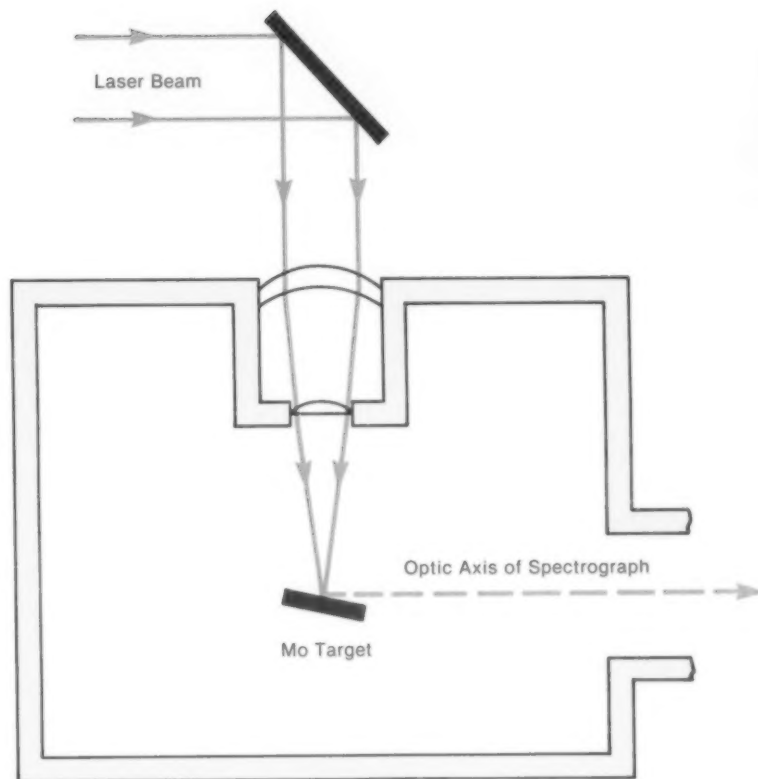


Figure 2—Schematic arrangement for focusing of laser beam to create laser-produced plasma. Light from the plasma is photographed by a concave grating spectrograph to obtain the spectrum.

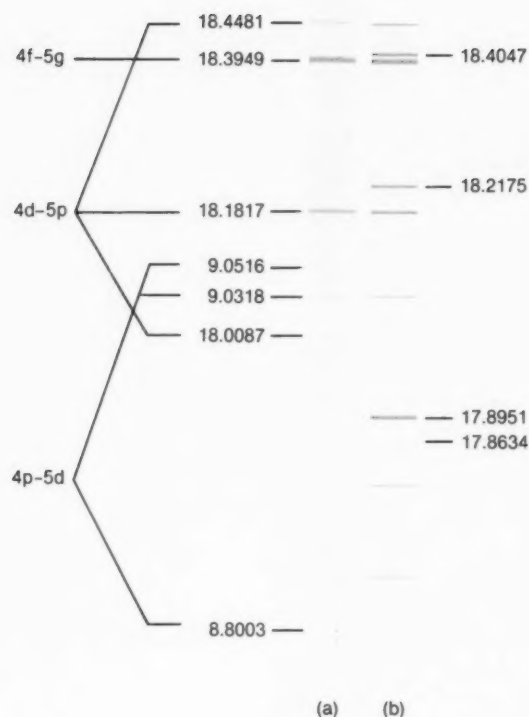


Figure 3—Spectra of Mo obtained from (a) laser-produced plasma; the indicated lines are due to Mo^{13+} and (b) low-inductance spark; the indicated lines are due to Mo^{7+} . This comparison demonstrates the selectivity of ionic species obtainable with the laser-produced plasma. Wavelengths are in nm.

spectrum was much simpler than the spark spectrum because it did not contain spectra of ions below Mo^{9+} . We also found that with the laser-produced plasma the spectrum of Mo^{13+} could be enhanced relative to spectra of higher stages of ionization by using laser pulses of greater energy and longer duration, typically 30 J in 20 ns. Finally, in the long wavelength region of the spark spectra, lines belonging to higher ionization stages could be recognized by their relatively large widths. In general, the observed line widths varied directly with the stage of ionization.

Results

From our observations, 35 lines of Mo^{13+} could be identified. The derived level system includes the series ns ($n=4-6$), np ($n=4-6$), nd ($n=4,5$), nf ($n=4-6$), and ng ($n=5-7$). The fine structure of the $4f\ ^2F$ term was found to be much smaller than predicted from theoretical calculations. Some very recent calculations carried out by K. Cheng and Y. Kim at the Argonne National Laboratory show that this anomaly is due to relativistic effects.

From our results an accurate value of the ionization energy could be determined. This was found from the ng-series to be 302.60 ± 0.04 eV.

This work has been supported by the Division of Magnetic Fusion Energy in the Department of Energy.

Reference:

See January 1979 issue of the *Journal of the Optical Society of America* for a detailed, fully annotated report on the spectrum and energy levels of Mo^{13+} .

There's
a new
look
to...

DIMENSIONS

... the monthly magazine of the National Bureau of Standards. Still featured are special articles of general interest on current topics such as consumer product safety and building technology. In addition, new sections are designed to ... PROVIDE SCIENTISTS with illustrated discussions of recent technical developments and work in progress ... INFORM INDUSTRIAL MANAGERS of technology transfer activities in Federal and private labs. ... DESCRIBE TO MANUFACTURERS advances in the field of voluntary and mandatory standards. The new DIMENSIONS/NBS also carries complete listings of upcoming conferences to be held at NBS and reports on all the latest NBS publications, with information on how to order. Finally, each issue carries a page of News Briefs, aimed at keeping scientist and consumer alike up to date on major developments at the Nation's physical sciences and measurement laboratory.

(please detach here)

SUBSCRIPTION ORDER FORM

Enter my Subscription To DIMENSIONS/NBS at \$11.00. Add \$2.75 for foreign mailing. No additional postage is required for mailing within the United States or its possessions. Domestic remittances should be made either by postal money order, express money order, or check. Foreign remittances should be made either by international money order, draft on an American bank, or by UNESCO coupons.

Send Subscription to:

NAME-FIRST, LAST																							
COMPANY NAME OR ADDITIONAL ADDRESS LINE																							
STREET ADDRESS																							
CITY												STATE				ZIP CODE							

PLEASE PRINT

- ☐ Remittance Enclosed
(Make checks payable
to Superintendent of
Documents)
- ☐ Charge to my Deposit
Account No.

MAIL ORDER FORM TO:
Superintendent of Documents
Government Printing Office
Washington, D.C. 20402

CONFERENCES

For general information on NBS conferences, contact JoAnn Lorden, NBS Public Information Division, Washington, D.C. 20234, 301/921-2721.

MITRE/NBS SYMPOSIUM ON LOCAL AREA COMMUNICATIONS NETWORKS

A three-day computer science symposium to provide an interchange of information on Local Area Communications Networks will be held in Boston in May 1979.

Scheduled for May 7 through 9 at the Copley Plaza Hotel, the symposium is co-sponsored by The MITRE Corporation and the National Bureau of Standards.

The two sponsors see their role as a catalyst in bringing together users and system developers from the government, military, industrial, and academic communities.

The symposium will consist of a series of plenary sessions and workshops. A number of invited papers will be presented discussing networks in use, systems in development, and leading edge research and development efforts at both system and component levels. The series of workshops will focus on specific applications and technological problems in such areas as communications protocols, standards, simulation, modeling, network control, and interconnections.

Attendance is limited by space requirements and will be held to approximately 300. The registration fee is set at \$175 and includes admission to all sessions and workshops, dinner the first day, and three luncheons. The fee also includes a copy of the proceedings.

Further information can be obtained by writing to Ms. Karla Edwards, The MITRE Corporation, Mail Stop A190, Bedford, MA, or by calling 617/271-3591.

CONFERENCE TO ADVANCE THERMAL ANALYSIS

A workshop aimed at advancing the state of the art of thermal analysis will be held at the National Bureau of Standards, Gaithersburg, Maryland, May 21-22, 1979.

Sponsored by NBS and the University of Akron, Ohio, the workshop is an attempt to improve communication on thermal analysis by bringing together researchers in different disciplines from industry, universities, and government. The workshop will provide researchers an opportunity to discuss their approaches to thermal analysis and ways of adapting various techniques for use in other fields.

Special emphasis will be placed on industrial technology, conservation and sources of energy, health, and basic scientific data. Included in the list of invited speakers are such internationally known experts as:

—W. R. Ott, Rutgers University, Piscataway, New Jersey, who will speak on ceramic processes and energy conservation.

—W. R. Bandi, U.S. Steel Research, Monroeville, Pennsylvania, who will discuss phase diagrams in alloys.

—D. Dollimore, University of Salford, United Kingdom, who will address the developments of thermal analysis in chemical processing.

—J. Rouquerol, Centre de Thermodynamique et de Microcalorimetrie, Marseille, France, who will review applications of thermal analysis to the study of technological absorbents.

Persons wishing to contribute to a poster session should send a 200-word abstract by April 30 to Professor P. D. Garn, program chairman, Chemistry Department, University of Akron, Akron, OH 44325. Authors will be notified as to whether their papers have been accepted for presentation by May 7.

To register for the workshop, write to Kathy Stang, B348 Materials Building, NBS, Washington, D.C. 20234, or call 301/921-3295. A fee of \$90 is being charged to all attendees to help defray the costs of conducting the workshop.

COMPUTER SYSTEMS CONFERENCES

A conference on Simulation, Measurement, and Modeling of Computer Systems will be held at the National Bureau of Standards, Boulder Laboratories, Boulder, Colorado, August 13-15, 1979. It is sponsored by ACM SIGMETRICS, SIGSIM, and the National Bureau of Standards.

Performance prediction techniques are employed during the design, procurement, and maintenance of computer systems. This upcoming conference is planned to recognize the activity in these specialized areas and to provide a forum for both applied and theoretical work in the disciplines of performance monitoring, modeling, and simulation of computer systems.

Topics will include:

Simulation and measurement during system design,

Model validation by measurement,

Simulation validation through analytic modeling,

Design specification and analysis,

Workload derivation and use,

Software validation models and measures, and

Evaluation of business information systems.

For further information contact: Paul F. Roth, B250 Technology Building, NBS, Washington, D.C. 20234 or call 301/921-3545.

CONFERENCE CALENDAR

April 3-4

TEMPERATURE COMPENSATION VOLUMES IN THE MEASUREMENT OF PETROLEUM PRODUCTS, NBS, Gaithersburg, MD; sponsored by NBS and NCWM; contact: Otto Warnlof, A211 Metrology Building, 301/921-2401.

April 4-5

SYMPOSIUM ON BUILDING SECURITY, NBS, Gaithersburg, MD; sponsored by NBS and ASTM; contact: John Stroik, A355 Building Research Building, 301/921-2107.

April 9-10

CONFERENCE ON NEUTRONS FROM ELECTRON MEDICAL ACCELERATORS, NBS, Gaithersburg, MD; sponsored by NBS, BRH, and AAPM; contact: Henry Heaton, C229 Radiation Physics Building, 301/921-2551.

April 19-20

5TH ROOFING TECHNOLOGY CONFERENCE, NBS, Gaithersburg, MD; sponsored by NBS and NCRA; contact: Robert G. Mathey, B358 Building Research Building, 301/921-2407.

*May 7-9

MEDILOG '79, NBS, Gaithersburg, MD; sponsored by NBS and DOD; contact: Charles Hulick, A740 Administration Building, 301/921-3465.

May 15-17

FEDERAL LABORATORY CONSORTIUM FOR TECHNOLOGY TRANSFER, SEMI-ANNUAL MEETING, NBS, Gaithersburg, MD; sponsored by NBS and the Federal Laboratory Consortium; contact: James Wyckoff, A400 Administration Building, 301/921-3814.

May 17

TRENDS AND APPLICATIONS SYMPOSIUM, NBS, Gaithersburg, MD; sponsored by NBS and IEEE; contact: Shirley Watkins, B212 Technology Building, 301/921-2601.

May 21-22

WORKSHOP ON THERMAL ANALYSIS, NBS, Gaithersburg, MD; sponsored by NBS and the University of Akron; contact: Oscar Menis, B326 Chemistry Building, 301/921-2813.

**May 23-25

MECHANICAL FAILURES PREVENTION GROUP, NBS, Gaithersburg, MD; sponsored by NBS and MFPG; contact: Harry Burnett, B264 Materials Building, 301/921-2813.

June 4-6

INTERNATIONAL CONFERENCE ON SYNCHROTRON RADIATION INSTRUMENTATION, NBS, Gaithersburg, MD; sponsored by NBS, Brookhaven National Laboratory, Stanford University, University of Wisconsin, Cornell University; contact: David Edwin, A251, Physics Building, 301/921-2031.

June 11-15

SYMPOSIUM ON ACCURACY IN POWDER DIFFRACTION, NBS, Gaithersburg, MD; sponsored by NBS, National Research Council of Canada, and the International Union of Crystallography; contact: Stanley Block, A219 Materials Building, 301/921-2837.

June 18-20

FOURTH INTERNATIONAL SYMPOSIUM ON ULTRASONIC TISSUE CHARACTERIZATION, NBS, Gaithersburg, MD; sponsored by NBS and NIH; contact: Melvin Linzer, A329 Materials Building, 301/921-2858.

June 21

18TH ANNUAL ACM TECHNICAL SYMPOSIUM, NBS, Gaithersburg, MD; sponsored by NBS and ACM; contact: Seymour Jeffrey, A247 Technology Building, 301/921-3531.

*June 25

MINORITY BUSINESS WORKSHOP, NBS, Gaithersburg, MD; sponsored by NBS and DoC; contact: L. Goodwin, A715 Administration Building, 301/921-3521.

July 22-27

NATIONAL CONFERENCE ON WEIGHTS AND MEASURES, Red Lion Motor Inn, Portland, Oregon; sponsored by NBS and NCWM; contact: Harold Wollin, A211 Metrology Building, 301/921-3677.

September 5-7

SYMPOSIUM ON EDDY CURRENT NON-DESTRUCTIVE TESTING, NBS, Gaithersburg, MD; sponsored by NBS, ASTM, and ASNT; contact: George Birnbaum, A363 Materials Building, 301/921-3331.

* New Listings

** April 16-18 postponed to May 23-25.

PUBLICATIONS

TEACHER AIDS

by Stan Lichtenstein

The following materials produced by agencies of the Federal Government are recommended by DIMENSIONS/NBS for their potential value to educators as supplements to the classroom or school library.

A Future from the Past: The Case for Conservation and Reuse of Old Buildings in Industrial Communities.

Vivid photographs—some of them depicting buildings that were later demolished or vandalized—support the message of this 119-page paperback. It argues for reasoned preservation of old buildings as a “means for the growth of new business activities, since the demand for new buildings generally comes from businesses which have had a chance to establish themselves in inexpensive quarters and to eventually grow to such a size that they require more space.” A joint publication of the U.S. Department of Housing and Urban Development and the Massachusetts Department of Community Affairs, the book includes sections on The Past in the Present, Four Industrial Cities, The Cost Benefit of Preservation, and Formulating a Strategy for Conservation in Industrial Communities. Limited number of copies available free from:

HUD

A Future from the Past

Room 7230

Washington, D.C. 20410

(stock no. 023-000-00435-6)

Purchase at \$3 a copy from:

Superintendent of Documents

U.S. Government Printing Office

Washington, D.C. 20402

Spinoff 1978: An Annual Report (NASA)

“Technology Twice Used” is a principal heading in this handsome, profusely illustrated report of the National Aero-

Lichtenstein is a writer and public information specialist in the Public Information Division.

nautics and Space Administration. That heading marks a section detailing spin-off applications of aerospace research to construction, public safety, health and medicine, sports and recreation, consumer products, transportation, food and agriculture, computers and communications, and community services. A typical example is a lubrication fluid originally developed for a series of NASA satellites, now found applicable in a commercial product “for protecting the sound fidelity of phonograph records.” Educators seeking a complimentary copy (limited number available) should write:

Walter Heiland

NASA Technology Utilization Division

P.O. Box 8756

Baltimore-Washington International

Airport

Maryland 21240

The book is for sale (stock no.

003-000-00712-4) at \$3.25 a copy;

order from:

Superintendent of Documents

U.S. Government Printing Office

Washington, D.C. 20402

ASTM-NBS-NSF Symposium on Fatigue Mechanisms

Embodying papers presented at the May 22-24, 1978 Kansas City, Mo., symposium, this 122-page paperback is rich in material for relatively advanced students of metallurgical science and engineering. The symposium was sponsored by the American Society for Testing and Materials, National Bureau of Standards, and National Science Foundation. For a free copy, while supply lasts, contact:

Dr. J. T. Fong

National Bureau of Standards

Room A302 Administration Building

Washington, D.C. 20234

DESIGN GUIDE FOR REDUCING NOISE IN AND AROUND BUILDINGS

Design Guide for Reducing Transportation Noise In and Around Buildings, Pallett, D. S., Wehrli, R., Kilmer, R. D., and Quindry,

T. L., *Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 84*, 176 pages (Apr. 1978) Stock No. 003-003-01687-0, \$3.50.*

A new handbook aimed at helping architects, builders, developers, and engineers reduce or control unwanted transportation noise in and around buildings has been published by the National Bureau of Standards.

Written by acousticians, architects, and psychologists at NBS, the book provides a quantitative method of calculating how and to what extent noise from autos, trucks, trains, and airplanes affects exterior and interior noise levels in a building.

Design Guide for Reducing Transportation Noise In and Around Buildings (Building Science Series 84) provides worksheets and step-by-step methods for identifying and predicting noise levels resulting from transportation system operations and for evaluating the adequacy of building designs with regard to environmental noise.

It also describes how to select noise criteria, that is, maximum acceptable sound levels appropriate for a particular site and proposed building. The guide also identifies and suggests design alternatives that may improve the acoustic conditions in and around buildings. In particular, the sound isolation provided by the building shell is estimated by means of a new “single figure rating” system.

COMPUTER OUTPUT MICROFORM STANDARD

Computer Output Microform (COM) Formats and Reduction Ratios. 16-mm and 105-mm, *Nat. Bur. Stand. (U.S.), Fed. Info. Process. Stand. Publ. (FIPS PUB) 54*, 15 pages (1978). Available from *National Technical Information Service*, Springfield, VA 22161.

The first in a series of standards to expedite the Federal Government's handling of computerized masses of data in microimage form has been issued by the National Bureau of Standards. Federal Information Processing Standard (FIPS) 54 establishes formats and reduction ratios

for computer-generated 16-mm and 105-mm microforms.

According to NBS, standard sizes and formats for the microforms should help agencies exchange and use recorded information by reducing the variety of equipment needed to produce and read the microforms.

FIPS 54 was developed by Federal Task Group TG-18, an interagency committee established to recommend standards for computer output microforms (COM). The standard applies to COM systems and microforms that are purchased by the Federal Government. It specifies the image arrangement, size, and reduction ratios for 16-mm and 105-mm microforms generated by computer output microfilm with effective reduction ratios for 24:1 and 48:1. Only business-oriented fonts similar to those produced by computer line printers are covered. Future standards in the series will be developed as needed to cover other applications.

PERFORMANCE CRITERIA AND PLUMBING SYSTEM DESIGN

Performance Criteria and Plumbing System Design, Orloski, M. J., and Wyly, R. S., Nat. Bur. Stand. (U.S.), Tech. Note 966, 61 pages (Aug. 1978) Stock No. 003-003-01963-1, \$2.40.

As an introduction to the subject, the traditional approach to plumbing system design, based on conditions flow, is reviewed. Then, recent research is discussed in some technical detail in order to explain the significance of time profiles of hydraulic parameters under dynamic conditions (representative of transient flow phenomena in plumbing systems).

The application of performance criteria based on this type of data can reduce excessive design factors and provide useful criteria for evaluating innovative systems. An example is given to illustrate a case where performance data permit relaxing requirements for vent design practice.

In addition, the report discusses the long-term implication of the performance

approach. For example, where measures of user satisfaction can be correlated with traditional design criteria under service conditions, the performance approach could be beneficially extended to other areas of plumbing design such as water distribution, storm drainage, and plumbing fixtures. Beyond this, it has been recognized that uniform guidelines and test methods for evaluation of innovative systems, based on research findings, are essential for wide acceptance of performance methods, particularly by the regulatory community.

This report also summarizes related research needs.

Building Technology

Arens, E. A., and Carroll, W. L., Geographical Variation in the Heating and Cooling Requirements of a Typical Single-Family House, and Correlation of These Requirements to Degree Days, Nat. Bur. Stand. (U.S.), Bldg. Sci. Ser. 116, 58 pages (Nov. 1978) Stock No. 003-003-01992-5, \$2.50.

Debelius, J. R., Ed., Building Technology Publications 1977—Supplement 2, Nat. Bur. Stand. (U.S.), Spec. Publ. 457-2, 113 pages (Aug. 1978) Stock No. 003-003-01962-3, \$3.25.

Keune, R. V., Assessment of Current Building Regulatory Methods as Applied to the Needs of Historic Preservation Projects, Nat. Bur. Stand. (U.S.), Spec. Publ. 524, 87 pages (Oct. 1978) Stock No. 003-003-01990-9, \$2.75.

Milton, H. J., Metrication in Building Design, Production and Construction—A Compendium of 10 papers, Nat. Bur. Stand. (U.S.), Spec. Publ. 530, 188 pages (Sept. 1978) Stock No. 003-003-01971-2, \$3.75.

Computer Science and Technology

Weatherbee, J. E., Ed., Computer Science and Technology: Computer Performance Evaluation Users Group (CPEUG). Proceedings of the Fourteenth Meeting held at Boston, MA, Oct. 24-27, 1978, Nat. Bur. Stand. (U.S.), Spec. Publ. 500-41, 353 pages (Oct. 1978) Stock No. 003-003-01985-2, \$6.

Health and Safety

Sores, C. G., and Ehrlich, M., Nationwide Survey of Cobalt-60 Teletherapy Dosimetry, Nat. Bur. Stand. (U.S.), Tech. Note 978, 40 pages (Aug. 1978) Stock No. 003-003-01968-2, \$1.60.

Stenbakken, G. N., Test Method for the Evaluation of Metallic Window Foil for Intrusion Alarm Systems, Nat. Bur. Stand. (U.S.), Spec. Publ. 480-34, 10 pages (Aug. 1978) Stock No. 003-003-01961-5, 90 cents.

Engineering, Product and Information Standards

Eisenhower, E. H., Chairman, ANSI Subcommittee N43-3.3, American National Standard N542; Selected Radioactive Sources, Classification. (ANSI N542-1977), Nat. Bur. Stand. (U.S.), Handb. 126, 28 pages (July 1978) Stock No. 003-003-01903-8, \$1.20.

Eisenhower, E. H., Chairman, ANSI Subcommittee N43.4, American National Standard N433.1; Safe Design and Use of Self-Contained, Dry Source Storage Gamma Irradiators (Category I). (ANSI N433.1-1977), Nat. Bur. Stand. (U.S.), Handb. 127, 22 pages (July 1978) Stock No. 003-003-01913-5, \$1.10.

Metrology: Physical Measurements

Beers, J. S., and Taylor, J. E., Contact Deformation in Gage Block Comparisons, Nat. Bur. Stand. (U.S.), Tech. Note 962, 46 pages (May 1978) Stock No. 003-003-01931-3, \$1.60.

Burley, N. A., Powell, R. L., Burns, G. W., and Scroger, M. G., The Nicrosil Versus Nilil Thermocouple: Properties and Thermoelectric Reference Data, Nat. Bur. Stand. (U.S.), Monogr. 161, 167 pages (Apr. 1978) Stock No. 003-003-01856-2, \$3.50.

Standard Reference Data

Heller, S. R., and Milne, G. W. A., EPA/NIH Mass Spectral Data Base—Molecular Weights 30-1674 and 1978 Indexes to EPA/NIH Mass Spectral Data Base, Nat. Bur. Stand. Ref. Data Ser., Nat. Bur. Stand. (U.S.), 63, Volumes 1-4 and 1978 Index, 4685 pages (Dec. 1978) Stock No. 003-003-01987-9, \$65.00/set.

Standard Reference Materials

Chang, T., and Kahn, A. H., Standard Reference Materials: Electron Paramagnetic Resonance Intensity Standard: SRM-2061; Description and Use, Nat. Bur. Stand. (U.S.), Spec. Publ. 260-59, 60 pages (Aug. 1978) Stock No. 003-003-01975-5, \$2.50.

* Publications cited from this point on may be purchased at the listed price from the U.S. Government Printing Office, Washington, D.C. 20402 (foreign: add 25%). Microfiche copies are available from the National Technical Information Service, Springfield, VA 22161. For more complete periodic listings of all scientific papers and articles produced by NBS staff, write: Editor, Publications Newsletter, Administration Building, National Bureau of Standards, Washington, D.C. 20234.

NEWS BRIEFS

FIRE SAFETY IN HEALTH CARE FACILITIES. A new NBS audiovisual program, "Flashover, Point of No Return," instructs health care personnel in the basics of smoke spread and control and fire "flashover." Flashover is the point at which a small, non-threatening fire suddenly becomes a violent force which can envelop an entire room in flames. A 12-minute slide/audio version is available for purchase from the National Audio-Visual Center, GSA, Reference Section, Wash., D.C. 20402 at \$27.75 (order #A00454). A 16-mm film version may also be purchased from GSA for \$69.50 (order #A00453). Free film loans are available by writing Association Films, Inc., 866 Third Avenue, New York, NY 10022.

WATER CONSERVATION RESEARCH PROJECT LAUNCHED. A water conservation research project has been started by NBS in cooperation with the Department of Housing and Urban Development. The project is intended to produce information to aid in reducing residential water use. The NBS work will lead to recommendations and guidelines applicable to the development and adoption of water-efficient plumbing fixtures, fittings, and appliances. The Stevens Institute will also be cooperating in this effort.

U.S. TAX LAW CHANGES AID HISTORIC PRESERVATION. Changes in Federal tax law have made rehabilitation of historic buildings significantly more attractive, according to Historic Preservation Incentives of the 1976 Tax Reform Act: An Economic Analysis. The new NBS report finds that--as intended--the tax law revisions are tipping the scale toward restoration and rehabilitation of historic structures instead of demolition and redevelopment. Order from U.S. G.P.O., Wash., D.C. 20402, SD Stock No. 003-003-02015-0, \$1.50.

NEW COMPUTER STANDARDS. A uniform means of representing local time of day, universal time, local time differentials, and U.S. time zone references is provided in two new NBS automatic data processing standards that will become effective for Federal agencies on August 1, 1979. These Federal Information Processing Standards, FIPS PUBS 58 and 59, are expected to be useful in typical operations ranging from processing a payroll to tracking a space vehicle, where computers must be able to exchange precise, clear information about time in mutually compatible formats. The standards are available for sale at \$4 each from the National Technical Information Service, Springfield, VA 22161.

FAST ANALOG-TO-DIGITAL CONVERTER. The fastest superconducting analog-to-digital converter yet reported has recently been fabricated and tested by the NBS-Boulder, CO, laboratories. A 4-bit A/D uses superconducting Josephson junctions and has operated at 200 MHz. The ultimate speed of the device should be in the range of 1-10 GHz, making it the fastest known A/D converter of any type. It also has greatly simplified circuitry.

NEXT MONTH IN

DIMENSIONS^{NBS}



As energy bills get higher, advice on how to save gets more valuable. See the next issue of DIMENSIONS and take the tips based on NBS research for maximum savings this summer.

U.S. DEPARTMENT OF COMMERCE

Juanita M. Kreps, Secretary

Jordan J. Baruch, Assistant Secretary for Science and Technology

NATIONAL BUREAU OF STANDARDS

Ernest Ambler, Director

Prepared by the Public Information Division
Washington, D.C. 20234

Richard S. Franzen, Chief

Madeleine Jacobs, Chief, Media Liaison and General Publications

Juli Chappell, Editor

Justine A. Williams, Assistant Editor

Stan Lichtenstein, Production Manager

Skip Wenner, Visual Editor
(Commerce Department)



PHOTO CREDITS

Photo on page 3 Courtesy of National Aeronautics and Space Administration.

Photo on page 5 Fred McGehan.

Correction: Photos accompanying the December article called "Testing for EMI," page 2, were taken by Kent Higgins and Dar Miner.

The Commerce Department's National Bureau of Standards was established by Congress in 1901 to advance the Nation's science and technology and to promote their application for public benefit. NBS research projects and technical services are carried out by the National Measurement Laboratory, the National Engineering Laboratory, and the Institute for Computer Sciences and Technology. Manufacturing, commerce, science, government, and education are principal beneficiaries of NBS work in the fields of scientific research, test method developments, and standards writing. DIMENSIONS/NBS describes the work of NBS and related issues and activities in areas of national concern such as energy conservation, fire safety, computer applications, materials utilization, and consumer product safety and performance. The views expressed by authors do not necessarily reflect policy of the National Bureau of Standards or the Department of Commerce.

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Annual subscription: Domestic, \$11.00, foreign, \$13.75. Single copy: Domestic, \$1.10, foreign, \$1.40. The Secretary of Commerce has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department. Use of funds for printing this periodical has been approved by the Director of the Office of Management and Budget through June 30, 1981.

AN EQUAL OPPORTUNITY EMPLOYER

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

OFFICIAL BUSINESS
Penalty for Private Use, \$300
RETURN POSTAGE GUARANTEED

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
COM-215



CONTROLLED CIRCULATION RATE

DNBS SERIA300SEISSDUE000R
SERIALS PROCESSING
UNIVERSITY MICROFILMS INTL
300 N ZEEB RD
ANN ARBOR MI 48106

